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# Low RF-field strength cross polarization combined with photo-induced non-persistent radicals for clinically applicable dDNP

## Work in progress

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## Cross Polarisation for SPINlab-like polarisers using non-persistent radicals is demonstrated.

The efficiency of the transfer from protons to carbon is modest at the currently achievable low  $B_1$  fields of 4-5 kHz still yielding  $^{13}\text{C}$  polarisation levels up to 15 %. Based on the presented results, we foresee polarisation levels superior to direct  $^{13}\text{C}$  DNP in our next generation of double-tuned probes incorporating local tune and match.

### Abstract

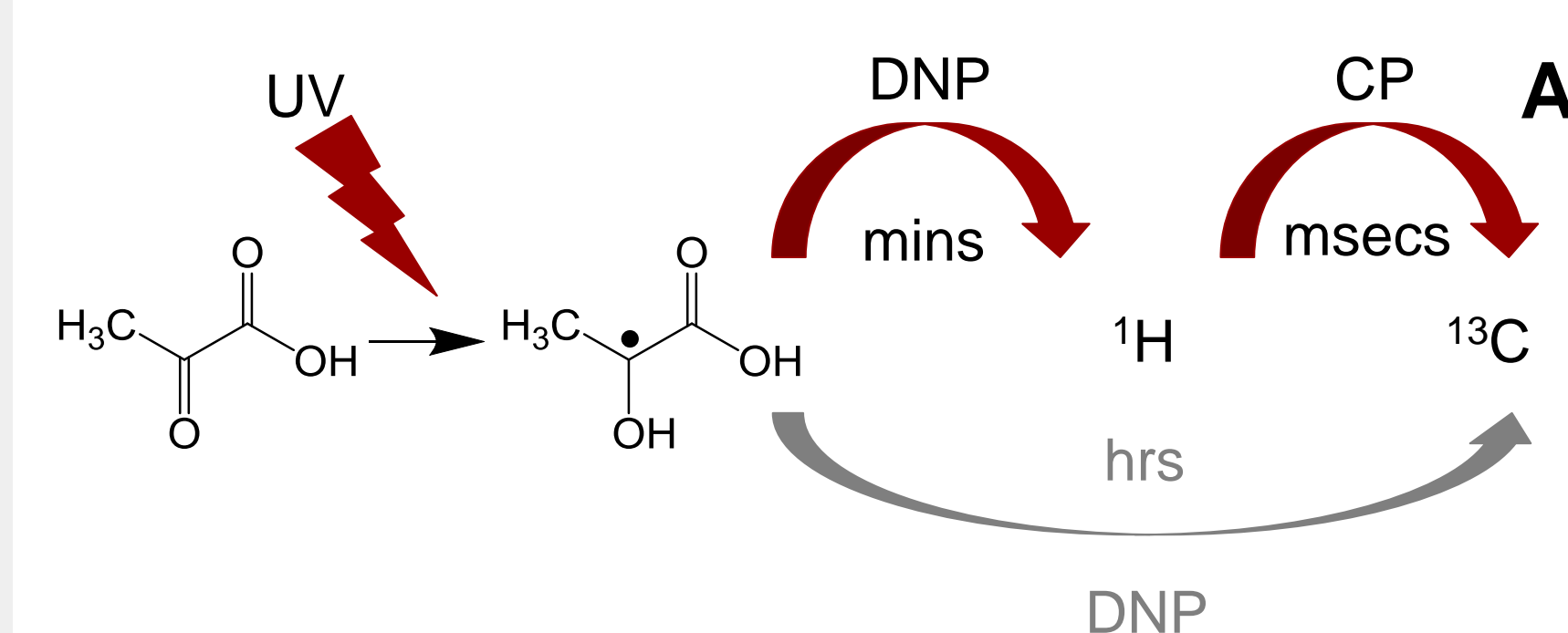
We demonstrate the possibility of  $^1\text{H}$  Dynamic Nuclear Polarization followed by cross polarization to carbon (DNP-CP) using a modified low cost benchtop console (Koa2) equipped with an external amplifier (Tomco) and a SPINlab-like dissolution DNP polarizer *i.e.* using the same fluid path and allowing for hyperpolarisation of a full human dose. Cross polarisation (CP) using Laboratory Frame De- and Remagnetisation<sup>1</sup> (LAFDR) was found superior to alternative sequences at the limited  $B_1$  fields employed. Faster build-up rates compared to  $^{13}\text{C}$  DNP are demonstrated using TEMPOL (4-Hydroxy-2,2,6,6-tetramethylpiperidine 1-oxyl) and DNP-CP  $^{13}\text{C}$  polarisations up to 15 % are achieved using non-persistent UV-induced radicals.

### Introduction

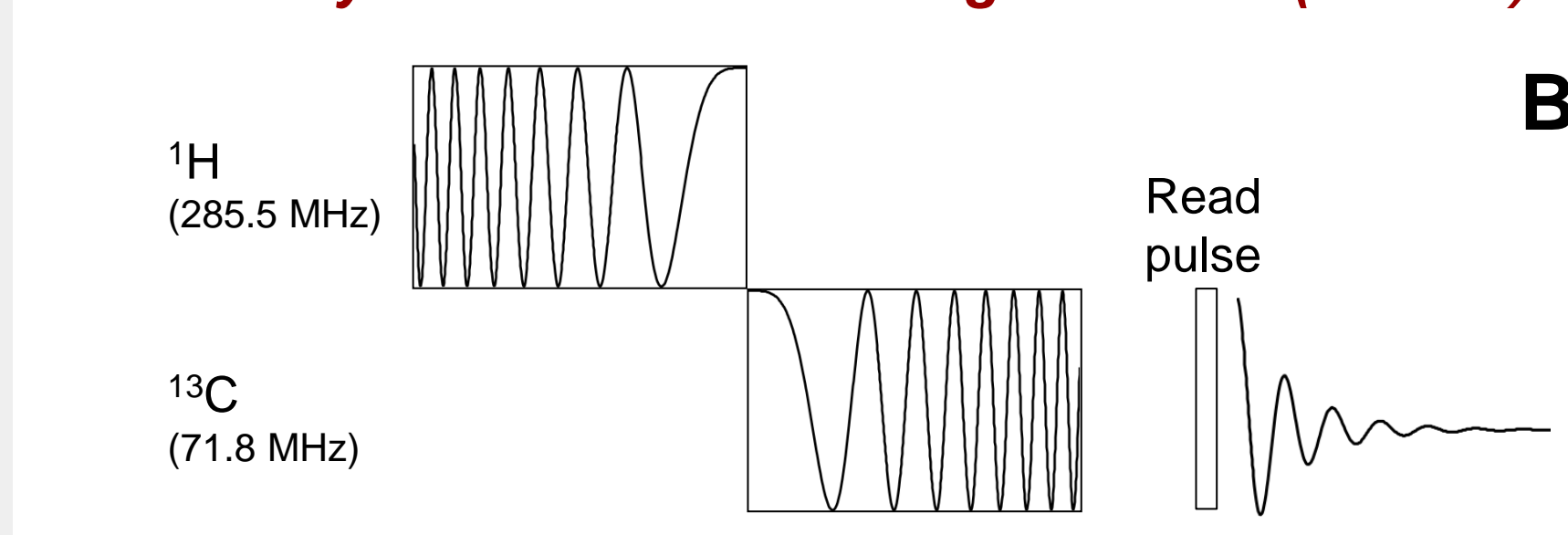
Dissolution Dynamic Nuclear Polarization (dDNP) is used to enhance the MR signals in imaging by factors of 10,000<sup>2</sup> paving the road for metabolic MR studies. However, the polarization build-up on  $^{13}\text{C}$  typically takes tens of minutes to hours, significantly lowering the versatility and throughput. Recently, studies have shown the possibility of speeding up the process by polarizing  $^1\text{H}$ , which has a faster build-up, followed by polarization transfer to *e.g.*  $^{13}\text{C}$ .<sup>3</sup> However, strong  $B_1$  fields and small sample volumes are used, which makes the technique incompatible with clinical dDNP-MRI. Moreover, for clinical use, and in general to eliminate the relaxation effect, the radical essential for DNP needs to be removed during dissolution. Use of pyruvic acid (PA) non-persistent photo-induced radicals for dDNP has been demonstrated to solve this issue<sup>4</sup> and recently polarization build-up on protons with  $\tau_{\text{DNP}} \sim 690$  s and 70 % polarization has been presented<sup>5</sup>.

### Methods

#### Overview

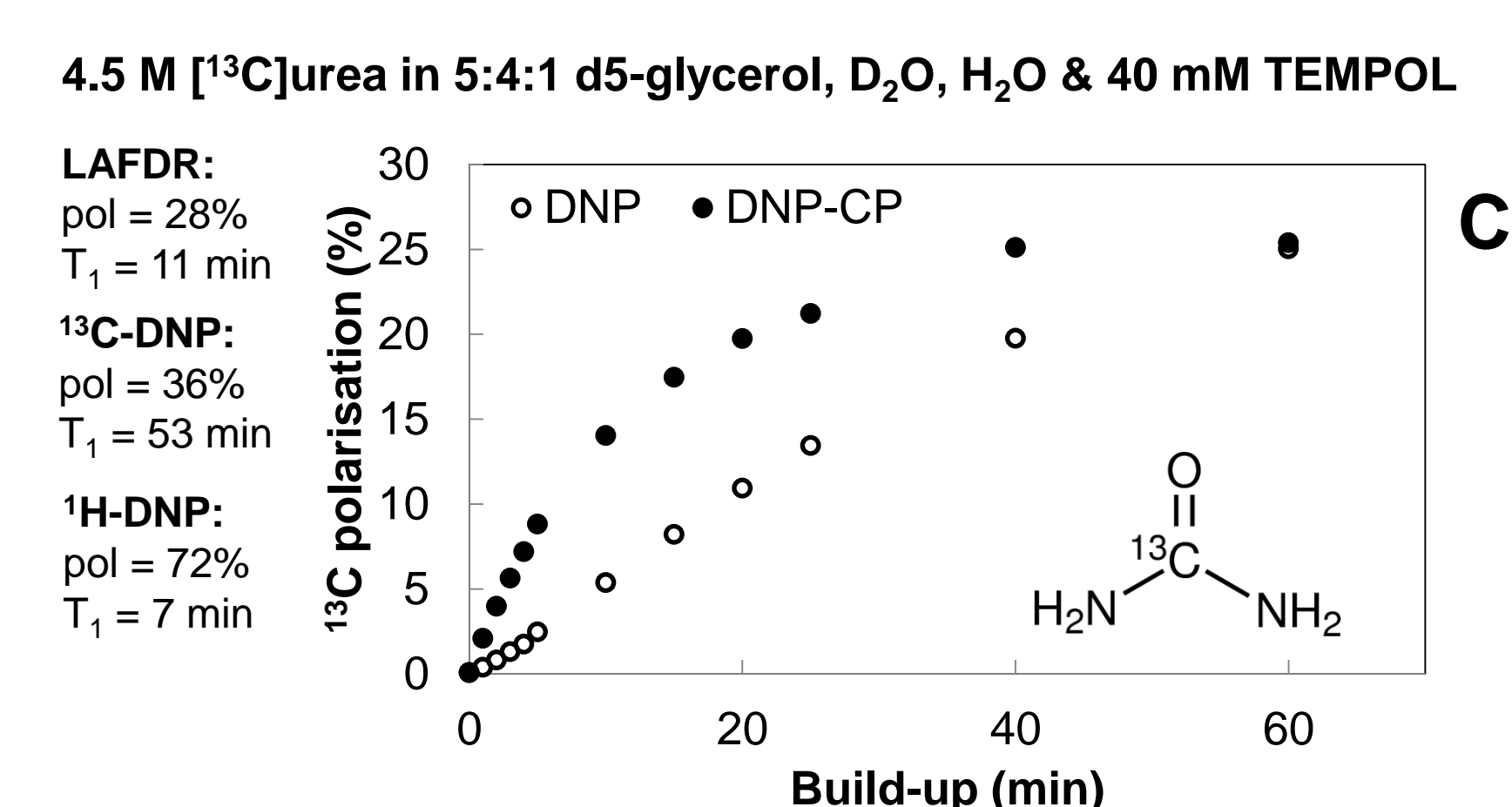


#### CP by Laboratory Frame De- and Remagnetisation (LAFDR)

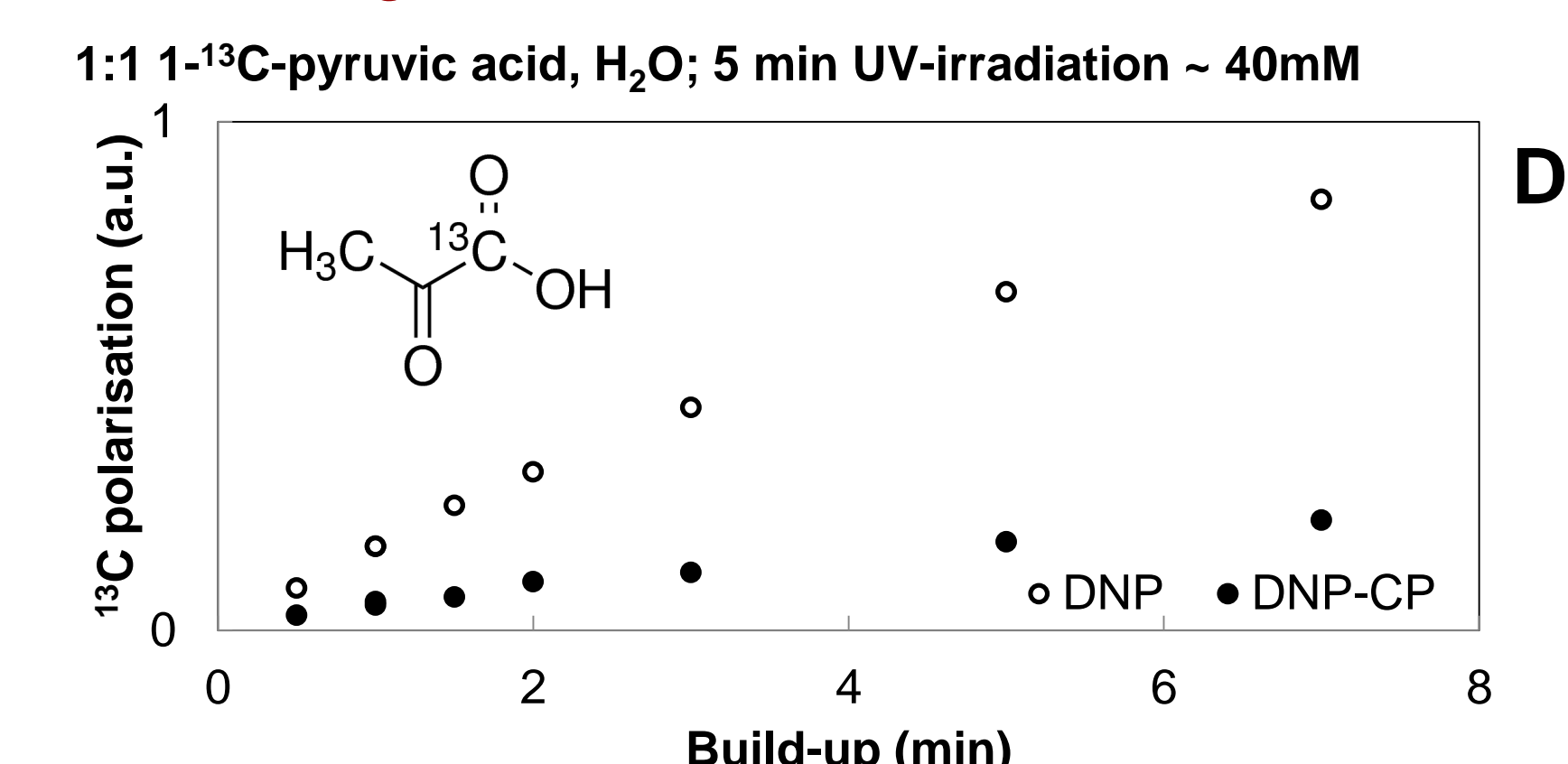


### Experimental results

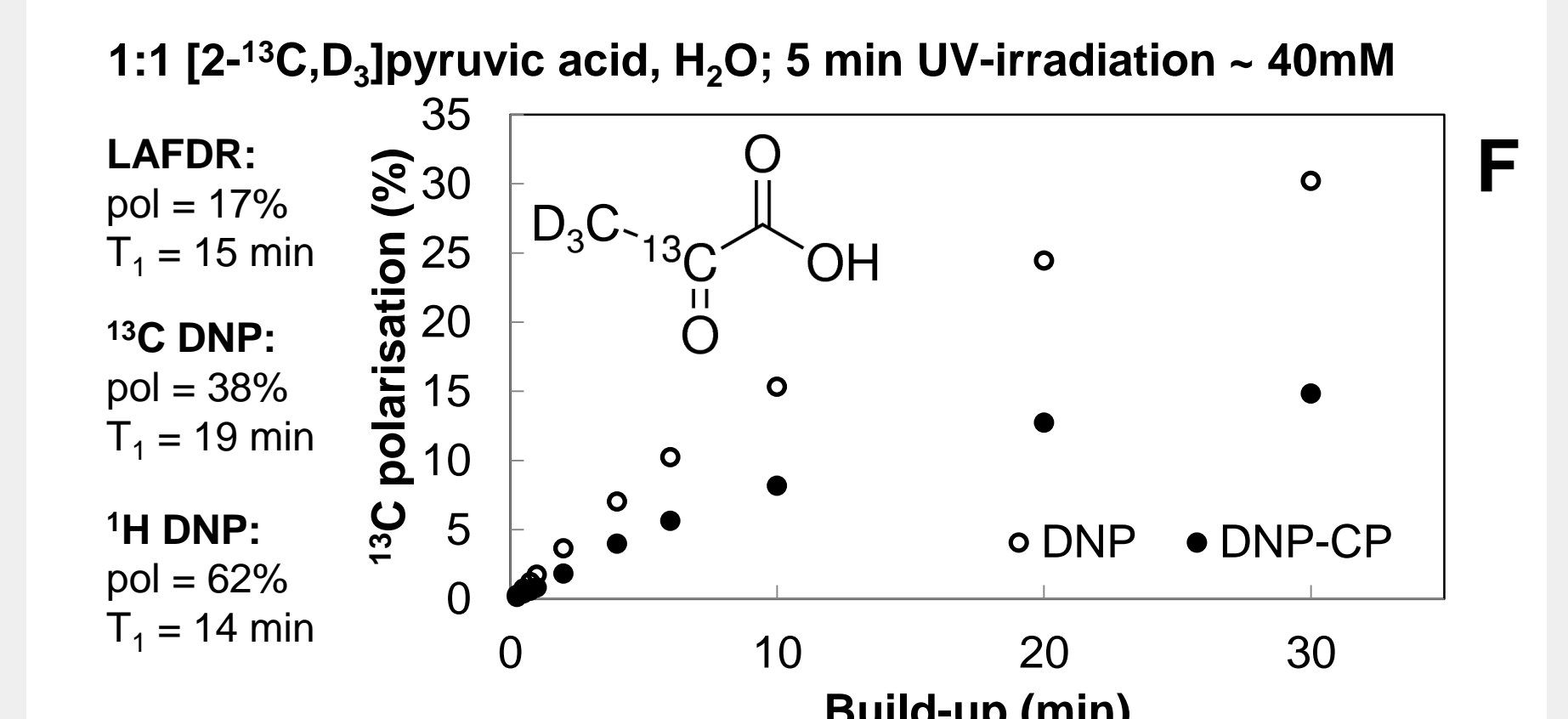
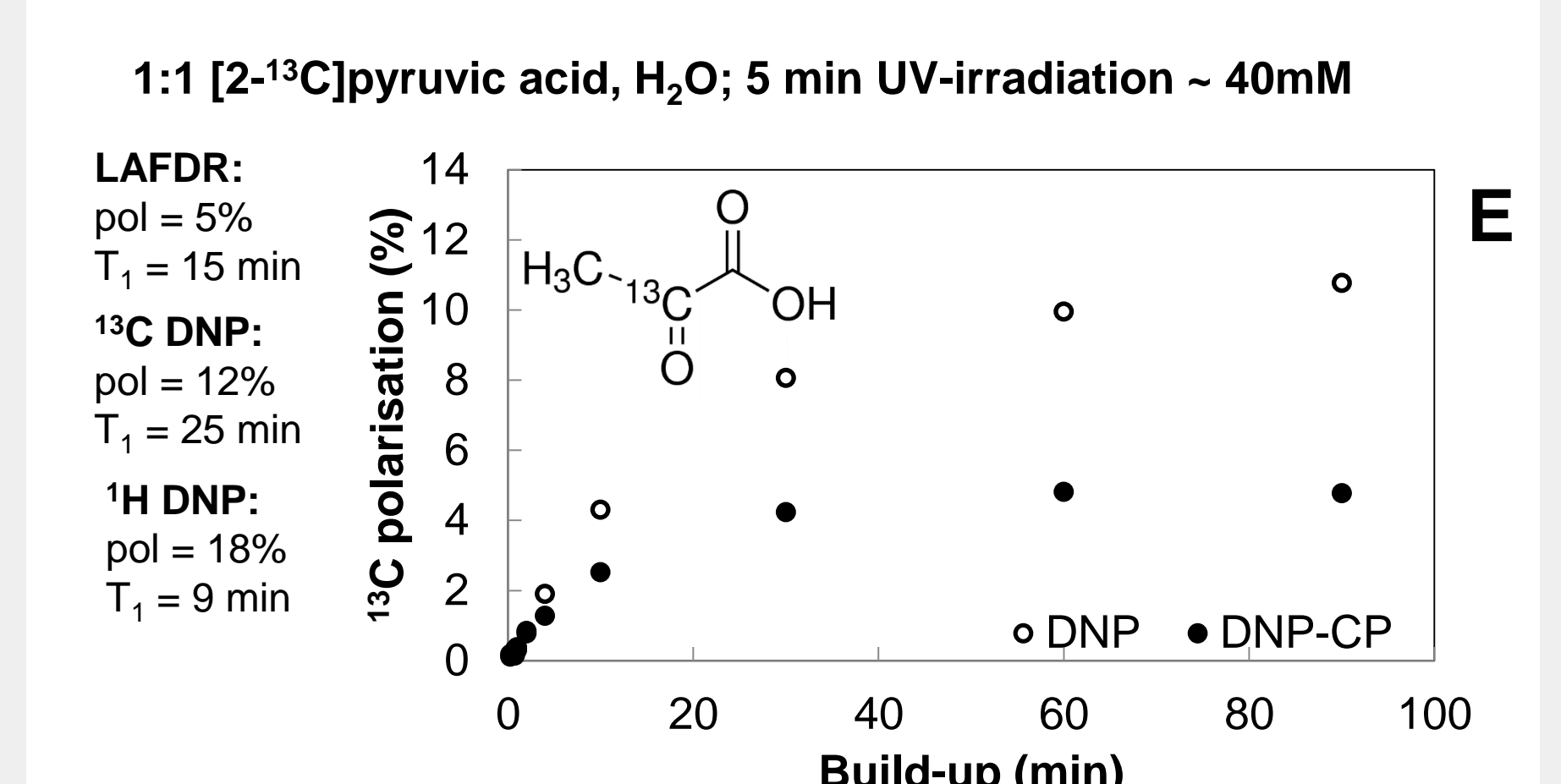
#### DNP-CP using TEMPOL as radical



#### DNP-CP using UV-induced radicals



#### DNP-CP using UV-induced radicals with broadened linewidth due to hyperfine coupling



### Results

The efficiency of DNP-CP depends on the build-up rate and final polarisation achieved on protons as well as the transfer efficiency of the CP sequence.

- For  $B_1 \leq 5$  kHz LAFDR (fig. B) was found to outperform other CP sequences (data not shown).
- On the TEMPOL containing sample, DNP-CP using optimised LAFDR outperforms  $^{13}\text{C}$  DNP for build-up times < 1 hour, and 20%  $^{13}\text{C}$  polarisation was achieved in only 20 min (fig. C).
- Using  $[1-^{13}\text{C}]$ PA as the substrate for non-persisting radicals gives a too narrow EPR-line for efficient  $^1\text{H}$  DNP resulting in poor DNP-CP performance (fig. D).
- Introduction of hyperfine coupling to the unpaired electron by  $^{13}\text{C}$  labelling in position 2 increases the EPR linewidth yielding fast  $^1\text{H}$  DNP build-up, but a polarisation of only 18 %, and therefore still inefficient DNP-CP (fig. E).
- Deuterating the methyl group of PA increases the  $^1\text{H}$  DNP polarisation to 62 % and maintains the efficiency of CP. This yields a final  $^{13}\text{C}$  polarisation of 15% after CP (fig. F).

### Acknowledgements

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### Conclusion and Outlook

We have demonstrated DNP-CP on a clinical-compatible SPINlab-like polariser using a low-cost benchtop console equipped with an external amplifier. Moreover, the technique has been combined with non-persistent UV-induced radicals. At the current state, with  $B_1 \leq 5$  kHz, direct  $^{13}\text{C}$  DNP still outperforms the DNP-CP. However, the goal is to implement local tuning of the probe to achieve sufficient  $B_1$  fields to increase the transfer efficiency. We expect that sufficiently strong  $B_1$  fields are achievable for this setup to outperform direct  $^{13}\text{C}$  DNP both with respect to build-up rates and polarisation levels.

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